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MARCH, 1929

Featuring

**Developments in Concrete
Pavement**

Hot Mix Highway Surfacing

Discharge over Side Weirs



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JOURNAL OF THE BOSTON SOCIETY OF CIVIL ENGINEERS

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OUTSTANDING DEVELOPMENTS IN THE CON- CRETE PAVEMENT FIELD OF TODAY

BY L. E. ANDREWS *

(Presented before the Highway Section B. S. C. E., January 23, 1929)

A GENERAL VIEW OF CONDITIONS

THE paving industry of today has become one of our major construction operations involving a total yearly expenditure at the present time of well over \$1,000,000,000 for all street and highway purposes. The State Highway Departments have become leaders in this development, due to the necessity of providing adequate transportation facilities for intrastate and cross-country traffic. The United States Bureau of Public Roads has assisted greatly in extending this work, due to Federal aid allotments. Practically all of the paving on main systems in this locality is of the hard surface type, and principally of concrete in neighboring states. Approximately 100 per cent of all new paving on state systems in New Jersey, New York and Connecticut is of reinforced concrete, and the same is true for most of the other large road-building states.

All of this activity is of comparatively recent origin, having taken place during the last twenty years, and the major portion of same since the war. Prior to 1910 there were practically no concrete pavements in the United States. The oldest one on record is that at Bellfontaine, Ohio, constructed in 1892 and still in service.

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The rate of increase in number of transportation units has outstripped the providing of adequate facilities for their most efficient use. This necessity is, however, the spur and driving power which is bringing greater development to the paving field every year. The industry is a continuing one. When street and highway systems are completed it will be found necessary to make extensions so that ultimate completion is pushed ahead indefinitely, particularly when maintenance features are considered. In 1926 the State of New Jersey was looking forward to the early completion of her original layout of 728 miles of state roads. During that year, however, extensions were planned bringing the total mileage up to approximately 2,000, and now the state, having provided the necessary finances, is launched upon this more extensive program which will, beyond a doubt, be extended as time advances and necessity warrants.

The highway engineer of today is confronted with something more of a problem than grading a roadway and placing a pavement upon same. He must decide upon matters of directness in alignment over longer distances; by-passing of built-up communities and cities; greater widths of pavement, roadway and right of way; adequate bridges for increased widths of pavement and weight of traffic; separation of slow and fast moving traffic; and separation of grades not only with railroads, but also with other heavily traveled highways. Problems involving these features are becoming a more common occurrence daily.

In keeping with progress along these lines the quality of pavement and the technique of its design and construction have also been immeasurably improved. Outstanding developments involve the following features which will be discussed in that order:

1. Design and Construction Features.
2. Measurement of Materials.
3. High Early Strength Concrete.
4. Curing Methods.
5. Early Opening to Traffic.
6. Specifications and Inspection.

DESIGN AND CONSTRUCTION FEATURES

Certain features of design have been brought about during the last few years which have been a decided help in developing better construction practices and thereby securing improved work in the field. Pavements which formerly were constructed full width, that is, from curb to curb in one monolithic section, are now built in strips or panels, the number of same depending upon the total width of the pavement.

The generally accepted width of panel is 10 feet. Recent action by the American Association of State Highway Officials and the United States Bureau of Public Roads in adopting the 10-foot width of traffic lane as best practice will do much to standardize this feature throughout the country. The practice in this and neighboring states is to construct the pavement one strip at a time. There are certain advantageous features connected with this method of procedure, among which are the following: one-half of the roadway width or more is left available for the use of local traffic, and in most cases for through traffic, therefore making the use and maintenance cost of detours unnecessary.

It is far easier to secure a good finish with a less amount of manipulation on a narrow strip than it is on a full-width pavement. This means better riding qualities and greater durability, when it is considered that an excessive amount of working of the concrete in order to produce evenness in the surface may bring about conditions which will cause future trouble, this being one of the reasons for scaling surfaces.

The adoption of the plane surface instead of the circular or parabolic crown means that, in general, lower total crowns may be used, the only consideration being adequate provision for longitudinal drainage and general appearance. The use of plane surfaces has simplified many of the construction operations, finishing tools being reduced to a straight-edge design. The checking of the subgrade can be more easily accomplished. Where numerous intersections and also warped sections must be met, the straight-line crown will adapt itself most readily. On wider streets involving multiple lanes, the intermediate points in the cross section formed by the intersection of parallel lanes may be set to such elevations as will produce the most desired effect. In other words, the transverse contour may be broken up to approximate a circle, or parabola, if this seems desirable.

The question of thickness is paramount. In times past many 5 and 6-inch pavements have been constructed on roads which later became heavy traffic arteries, with the result that such pavements have often failed to give the best results. The average thickness of modern concrete pavements being constructed in this locality is 8 inches, and the tendency has been to increase this thickness on particularly heavy traffic highways. It is interesting to note that last year the State of New Jersey adopted a uniform thickness of 9 inches as the standard section for use on state highway work. New York State has adopted an average thickness of 8 inches, and in many instances is building pavements 9 inches in thickness. There are also many cases where a 10-inch uniform depth is being adopted on important sections.

One of the important developments taking place in the last few years, and particularly during the past year, has been that of the "small aggregate top pavement," sometimes spoken of as the "fine aggregate top" or "two-course concrete pavement." This type, monolithic in every sense of the word, is placed under the same conditions as the ordinary type of one-course pavement, the only difference being that the concrete for the upper 2 inches or more is made with a coarse aggregate ranging in size from one quarter to about five-eighths inches. Such a concrete has very important qualities of workability, and this is the principle reason for its adoption, the idea being to construct a surface which can be struck off and finished with a very minimum amount of manipulation. In actual practice this pavement may be completely finished with one striking and one belting. In so doing no excess water is brought to the surface, and it may be readily seen that such concrete is of the same quality from top to bottom, thus making the likelihood of any future scaling or surface disintegration, assuming the materials are good, very remote. In some sections of the country, due to certain conditions, much trouble has been experienced with scaling. In many places this type of pavement has been adopted as the remedy, and has proved very successful. The only additional equipment necessary is an extra bin and hopper for batching the coarse aggregate for the top course. Generally both classes of concrete are mixed in the same mixer, although there is an advantage in using separate mixers for both top and bottom concrete, in which case the work is speeded up and additional cost of equipment offset in this manner. The New York State Highway Department has adopted this type of pavement for use in western New York very successfully, with practically no increase in cost over the usual type of construction.

Concrete control methods are doing much for the industry today. The production of good concrete is merely the summation of good practices all along the line, from the selection of materials to the final curing and opening of the pavement to traffic. Any one of a considerable number of operations performed in the wrong manner may tend to nullify all of the other efforts which have been put forward to produce a satisfactory job.

Present-day practices provide that maximum mixing water for concrete be specified and definitely controlled on the job. Last year 30 per cent of the State Highway Departments specified the allowable amount of mixing water, and it is safe to say that this year will see this percentage considerably increased. The amount of total water content, other things being equal, is a criterion of strength which, when coupled with other desirable features of consistency and workability, forms the best insurance

in producing durable concrete. Such features of control are being written into paving and other concrete specifications every year, and are recognized as standard practices in the concrete field today.

MEASUREMENT OF MATERIALS

Chief among the concrete troubles in the past has been that of uniformity in consistency and general make-up of the mix. Some time ago it was recognized that this difficulty resulted largely from inaccurate measurement of materials, and as a result on all important work materials are now measured by volume or other method. It is now recognized, however, that even carefully struck-off volumes, unless corrections are made for the bulking effect of the damp materials, will not produce uniform quantities. In order to further improve proportioning methods the weight batcher is beginning to obtain a very prominent place. For a number of years past several of the middle western states have used weight batchers for aggregates. Just recently this practice has crept into the specifications in the East. The specifications of the highway departments of Pennsylvania and New Jersey provide that either volume or weight measurements may be used, and outline methods and corrections to use in either case in order that constant quantities may be obtained. The American Association of State Highway Officials and the United States Bureau of Public Roads have adopted weight proportions as a standard method and requirement, which action will do much toward bringing about the general adoption of this more accurate method of measuring materials. The percentage of error in uncorrected weight batching will be the moisture content of the aggregates. This will probably average not more than 4 or 5 per cent, and may be easily corrected by adding an additional quantity of material to offset same. The percentage of error in volume batching, due to bulking of the sand caused by moisture content, may vary from 10 to 30 per cent by volume, due to such condition.

HIGH EARLY STRENGTH CONCRETE

The use of high early strength concrete is of particular importance to the highway engineer because of the fact that it so often suits his purpose, particularly where intersections must be opened to traffic as early as possible, or the pavement in some other location, for a particular reason, must be opened without delay. It involves the use of standard Portland Cement, using a richer mixture, a longer mixing period, of from two to five minutes, and the very minimum amount of mixing water.

Any one of these features will contribute to a higher early strength, and the use of all of them will, under proper conditions, produce a concrete which may be opened to traffic in from 24 to 48 hours' time.

On maintenance work in the State of New Jersey mixtures of 1-1-2, using a total of $4\frac{1}{2}$ gallons of water per sack of cement, and a mixing period of five minutes, together with calcium chloride, has resulted in a concrete which has been opened to traffic in as short a period as 24 hours' time. In fact, the regular paving mixture of about $1-1\frac{3}{4}-3\frac{1}{2}$ has been used with minimum water, a maximum mixing period, and 2 per cent calcium chloride in producing concrete which has been safely opened to traffic in from 36 to 48 hours' time.

The results obtained in the State of Connecticut are of interest because all pavements are ready for traffic at the end of from five to seven days. The conditions there provide for the use of a mixture of $1-2-3\frac{1}{2}$ and a mixing period of $1\frac{1}{4}$ minutes, using approximately 5 gallons of water per sack of cement, together with a 2 per cent calcium chloride solution added for curing and high early strength purposes. A modulus of rupture of 500 is secured in about five days.

Similar experiences are being observed elsewhere; for instance, in the city of Rochester during the past season, concrete mixtures of 1-2-3, mixing period of $1\frac{1}{2}$ minutes, and wet curing methods have resulted in average compressive strengths of 3,000 pounds per square inch in seven days. Where strengths such as these are obtained there is no reason why the pavement cannot be opened up to ordinary traffic in one week's time.

It can be said, therefore, that improved methods in modern pavement construction have made it possible, under proper temperature and curing conditions, to reduce the time during which pavements were formerly closed to traffic from three weeks to one week.

CURING METHODS

The effective curing of concrete pavements is, perhaps, one of the most important operations in connection with pavement work in general, and at the same time, poor curing or lack of curing may do more than any other one thing toward cutting down the strength of the concrete and producing a permeable surface. Therefore every effort should be put forth to see that the curing is properly performed and started at the right time. The strength of the concrete increases very rapidly under proper conditions during early ages. If this process is materially retarded during this period, the strength which otherwise would have been

obtained may never be reached, and the entire work will be of a lower quality than otherwise would have been the case. Wet curing should start as soon as possible, that is, during the same day that concrete is placed, and as soon as covering material may be applied without marring the surface. The usual and best practice is to cover the top of the pavement with strips of wet burlap as soon as same can be used without damage to the concrete, and then wet down and kept saturated during the entire curing period, or until removed and replaced with some other suitable material. Usually the wet burlap is replaced with wet hay on the following day, and this in turn must be kept saturated during the balance of the curing period. It would be much better to thoroughly wet-cure the pavement during the first three days than to delay curing operations for three days and then perform same properly for the next week or so.

In numerous instances engineers have cast about for some other and perhaps easier or more positive method of curing pavements. For instance, in the State of Connecticut, calcium chloride at the rate of approximately 2 pounds per sack of cement is added in solution at the time of mixing, in order to accelerate the setting up of the concrete, thereby cutting down the necessary length of curing period. In this case the pavements are wet-cured with saturated burlap for a period of 30 hours, after which same is removed and the curing operation is considered to have been completed. This procedure is used in numerous other states and localities. Calcium chloride is effective principally as an accelerator, and wet-curing during the early stages must not be omitted. In general, tests should be made with the calcium chloride and brand of cement proposed for use, in order that the most effective quantity of calcium chloride may be decided upon. Generally this amount will be about 2 per cent.

Calcium oxychloride, "Cal.," is also often used as an accelerator, being added in dry form at the time of mixing. The amount used varies from 5 to 8 per cent.

Just recently light bituminous surface treatments have been applied to finished concrete in the form of a spray, not marring the surface and producing a film which will presumably cut down or eliminate the evaporation of water through the surface of the slab. These treatments do not penetrate the surface, but merely form a seal for the top. In some instances asphalt emulsion is used, and in other cases a specially processed asphalt. Where such surface applications have been made no other form of curing operation is used. These methods have been used experimentally in a number of the eastern states, and several mu-

municipalities in New Jersey have adopted same as their standard curing practice. The State Highway Department of Tennessee is at the present time conducting a series of field experiments with approximately twenty different methods of curing involving the bituminous treatments, in order that data may be secured as to the effectiveness of each over a period of time. The indications are, therefore, that paving engineers fully appreciate the value of proper curing, and are investigating ways and means of securing same by the most fool proof and best means possible. There is no doubt but what water curing is the most desirable method if same can be effectively secured. However, it is the lack of such effectiveness that is making other methods popular in some localities, and the test of time will determine definitely the value of each.

EARLY OPENING TO TRAFFIC

Ten years ago it was considered necessary, in some cases, to keep concrete pavements closed to traffic for a period of one month. This time has been gradually reduced until now, at least in this section of the country, pavements are generally closed to traffic for a period of about two weeks. Due to better concrete-making methods, and to the more general adoption of testing, both on the job as well as in the laboratory, this period has in numerous instances been reduced to a week or less, and it is confidentially felt that pavements which are properly constructed in the future will have attained sufficient strength for opening to traffic in a period of one week. Test reports on concrete from all sources have shown improvement in strength, other conditions being equal, from year to year. It is interesting to note that in many instances during the past year, field and laboratory tests have shown that 3,000-pound concrete was developed in a period of one week. Pavements of this strength are certainly strong enough to take ordinary traffic, and the opening and use of same should be encouraged where the continued exclusion of traffic is bound to work a hardship on abutting owners and traffic in general. It is felt, therefore, that in general, the closing of pavements to traffic under ordinary conditions, taking into consideration proper curing temperatures, can be reduced to ten days, and in other instances to even less time, as may be indicated by test results. Where it is felt desirable to open pavements at very early ages, such as one or two days, high early strength methods of producing concrete may be followed as previously outlined.

The ability to open pavements at early ages will do much for the paving industry, including the advantages obtained for base courses as

well as wearing surfaces, and every effort should be made to take advantage of the generally accepted methods of control which are being so advantageously carried out where used.

SPECIFICATIONS AND INSPECTION

While the technique in the design and construction of pavements has progressed far, there still remains much to be accomplished toward the adoption of better and more standardized specifications. The State Highway Departments in general set an example in each state for best practice, and there is a great similarity between the specifications of states in this locality. However, there is room for a vast improvement in many of our cities and smaller municipalities. It is encouraging, however, to note the interest which has been taken recently toward improvements along this line. It is felt that in the near future many of the radical variations may be smoothed out and general standards involving best practice adopted.

Perhaps one of the weakest points in the paving industry, especially in municipal work, is that of proper inspection. In the last analysis the quality of the work depends upon the engineer and inspector on the job, and if they are not equipped through training and experience to appreciate just what steps should be taken to insure success, the result may fall far below that which would otherwise be the case.

THE HOT MIX TYPE OF HIGHWAY SURFACING

BY HOWARD C. HOLDEN *

(Presented before Highway Section, B. S. C. E., February 27, 1929)

It may be of interest to review briefly some of the earlier methods used in the placing and mixing of this type of surface.

In the early days the sand-asphalt surface, known as the layer type, was first placed in the town of Eastham in 1905. Compared with the modern method of spraying asphalt the operation was very crude. An upright tank, similar to an enlarged "hogshead," was used as a container and hauled by four horses. The subsoil of sand was roughly shaped and harrowed with a disk or wheelharrow, so one can readily imagine how it was rutted by the wagon, and the holes caused by hoof imprints. The flow of asphaltic oil was controlled by a gate valve. This controlled the amount delivered to a distributor pipe having holes bored through it, the holes being about one-half inch in diameter and about 3 inches apart. The effect was a very streaked application. Later the A. T. C. distributor was used (which some of us remember). The asphaltic oil was distributed through nipples on to a splashboard and to the road surface. This was an improvement, but still very crude. One wonders now, when he visualizes these methods, that as good results were obtained. The bitumen consisted of 85 per cent asphaltic oil. Applications consisted generally of two, of about three-quarters gallons per square yard, the first application being covered with sand and back-covered daily for about a week. The surface was then broomed as clean as possible and the second application applied. This type with constant maintenance produced an uneven road surface, and is now occasionally built by towns in Barnstable County on unimportant roads. However, at the present time the subgrade is hardened, properly shaped and the bituminous material applied with uniform distributors under proper pressure.

The oldest highway of the sand mix type now in use on our state highway system is on National Route 6 in the town of Sandwich. The mixing operation for this project was carried on by placing a fixed volume

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of sand in a box similar to the old-time mortar box, and adding the proper amount of 90 to 100 penetration asphalt and raking it back and forth until the same particles were coated. This product was wheeled in barrows or carted to the highway and spread in one course to a thickness that would roll to 3 inches, first rolling with a hand roller, then a horse roller, and generally a final rolling at some later date with a 10-ton 3-wheel macadam roller. This highway surface is still in use and extends from the Bourne-Sandwich town line to the village of Sandwich. This surface was placed in 1913, and since it has received two surface treatments of one-quarter gallon each of 85 per cent asphaltic oil. Each time it was covered with clean, sharp sand. Soon followed the use of cylindrical dryer and cube mixers, which established a portable plant, also the semi-portable plant, and the permanent plants of a larger type.

At the present time the Sandwich project is the only hand-mixed surface of this type which has not been resurfaced, except one short section in the town of Mashpee, near the Barnstable line. The Sandwich highway today is narrow, supercrowned, and reconstruction must soon occur. From 1912 to 1922 very little attention was given to selecting sands which were properly graded, in general, a fairly coarse, clean sand being used in the mix, the one exception to this being in 1917, when 5 to 10 per cent by volume of Portland Cement was added to the mineral aggregate. Very naturally this somewhat increased the asphalt content. At this time it was decided that while excellent results were obtained by using the Portland Cement as a filler, it was felt that the results were satisfactory using local sand, and the cement filler increased the cost of the surface beyond the value received. Until 1920, on all of the so-called sand and oil-mix surfaces, on completion of the surfacing the surface was sealed with two applications of one-quarter gallon each of 85 per cent asphaltic oil, and the surface covered after each application with sand.

Prior to 1921 this type of surface was always placed in one course. Very often during the summer months the section placed in the afternoon was not rolled until the following day. This did not give proper compression, and in a short time traffic created inequalities of surface. The lack of using side forms, together with the excessive crown and narrow width, caused the edges to break down under traffic. Today, with the lesser crowns and the use of wooden side forms on the top course, and with the base course slightly widened, the breaking down of edges has been corrected.

In 1922 quite extensive experiments were conducted in Wellfleet. At that time it became evident that it was necessary to increase the

stability of this type of surface — to ascertain just what could be done to prevent displacement of the surface when loaded vehicles stood upon the surface during the season of high temperature; that certain factors were important, namely, load, time and temperature, and the depth penetrated by load; and just what could be added to the mineral aggregate to increase the stability of the surface. To ascertain this we used the rod penetration method, which is, briefly, a rod of certain cross-section area held in position by a small tripod and fixed loads added for a fixed time. The experiments with load and time applied were carried out during approximately the same temperature, thus obtaining comparative results from the different mineral aggregates used, which consisted of sand, stone screenings and hydrated lime in various amounts. At this time we had no method of arriving at density determination other than visual inspection. However, very careful observation of time of rolling and temperature of mix on the road surface was kept. At this time it was found very desirable to place the surface in two courses, and we also used side and center forms of wood, and the practice of using forms has been continued until the present time. Original rollings were done with a 6-ton tandem roller, and final rollings with a 10-ton 3-wheel macadam roller. It was found the same results were obtained with the tandem as with the 3-wheel roller. This conclusion was arrived at by the use of the rod penetration method, and comparing load, time, temperature and penetration.

The use of this simple device also provided an approximate idea of impact or stability value where these experiments were tried. First, the load was applied to the rod and as near uniform blows as possible were used, and a record of the number of blows and the character of the results were studied. From these various experiments was created our present Type A Bituminous Concrete Specification. I should add that many screen tests of sand were made, curves plotted on cross-section paper, and we thus determined the most desirable grading of sand particles. Mr. G. H. Delano was district engineer in District 7 at this time, and to him should be credited the persistent effort to improve this type of surface, which has become known to the Department of Public Works as Bituminous Concrete, Type A.

The Type A surfacing is the type most commonly in use at the present time. In addition to the mileage of this type of surface on the present state highway system there exists many miles in southeastern Massachusetts on roads built entirely by the towns, also a large mileage exists on chapter 90 or co-operative projects, where state, county and town provided funds. These chapter 90 projects were built under the supervision of the Department, and are maintained by the towns. A very

economical type has been constructed on chapter 90 work by crushing gravel and using the larger product of the crusher for a base course, filling the voids in the base with the finer aggregate, or penetrating the base course with refined tar or asphalt, and over which has been placed a top course of 2 inches, using the finer aggregate from the crusher product. This type, with the base course of crushed gravel which has been varied from 2 to 4 inches in thickness, gives a more stable surface.

Much of the sand and asphalt work done in Barnstable, Dukes and Nantucket Counties has been resurfacing and widening, as well as just widening the old water-bound macadam and reducing the crown. It has not been the custom to scarify the old macadam surface; simply place the full thickness of the base course on the widened portion, and true up the old macadam surface to a uniform cross section, and then place the top course of 2 inches in thickness. This has provided a very economical method of resurfacing as well as one which has been very satisfactory.

The highways constructed and reconstructed with this type of surface are within an area which, during the summer months, carry a medium to heavy automobile travel, but are not subjected to heavy truck traffic. In Barnstable, Dukes and Nantucket Counties the law limits the load, including vehicle, to 10 tons. I do not recommend this type of surface for a highway over which passes a large number of heavy loaded vehicles. On November 30, 1928, the total mileage in District 7 of this type of surface was 157.94 miles, and the surface maintenance cost without surface treatment was \$45.68 per mile, while the surface cost for the 157.94 miles, including the surface treatment, was \$102.34 per mile.

This type of surface is simple to repair, as plants are quite numerous in Barnstable and Plymouth Counties. The customary method of making surface repairs is to cut out the section that needs repair. By this I mean removing the top course, painting the edges of the section, cut out lightly, and spattering the base course with bitumen so as to give a cobweb effect. It is customary to buy this material from the various local plants all mixed, and fill in the areas cut out and roll it with a hand roller, and, if available, use a tandem roller. The bituminous concrete or sand asphalt surfacing material can be hauled for quite a long distance. If it has a tendency to cool it can be covered. Also when rolling with a hand roller the type that can be filled with hot water can be used in cold weather. After the surface patch is made it can be sealed, and the patches present very nearly the same appearance as the original surface.

During the past few years a special effort has been made to correct inequalities in the surface, not only on this type but on all types

of surface. On this particular type of surface, to increase the density, equipment has been placed on the rollers so that they are wet with water, and this has prevented the picking up of the surface, and the rolling has been done sooner after the surface material has been placed. In the initial rolling care should be used that the roller travel parallel to the center line of the pavement, beginning at the edge and working toward the center, being sure that the roller shall overlap the preceding one about one-half the width of the roller. It is important that the roller, when changing direction, does not stand on the hot surface, and it is necessary that the rakers resmooth the surface at the point where direction is changed. This particular type of surface is pliable when hot, and inequalities in the surface, such as low spots, high spots or depressions, can be raked out and then hot additional material can be added to correct this condition, but immediate rolling should occur after additional material has been added. During the past year all projects have been equipped with straight edges 10 feet in length, and a great deal of attention has been paid to correct the irregularities by the use of this straight edge, and all low or high spots one-fourth inch and over have been marked with yellow crayon and rolled out. This operation has been continued until the surface is free from such irregularities. During 1928 the Federal government placed inspectors on various Federal aid projects, primarily to study methods and to see if suggestions could be made to reduce the cost to the contractors in the placing and manipulation of this type of surface. Quite intensive studies were made by them for density determinations. During this study two density determinations of ten complete sets of cylinders were made. A 2-inch steel pipe sharpened on one end was used to take samples, the first sample being taken as soon as the roller had passed over the surface, and they were able to force the core cutter through the top course by hand. After further rolling, it was necessary to drive the core cutter through the surface, or use a jack, and jack through the top course to obtain the sample. The core cutter was lightly oiled with linseed oil and the sample could be easily pushed out. Continuous samples were taken until the final rolling occurred. A careful record of temperature was made at the time of rolling, and the temperature of the air was taken when the final core was obtained. The results they obtained were interesting, and it was found that the density was practically the same, whether the surface was rolled with a 6 or 9 ton tandem roller.

In the fall of 1928 experiments were conducted using ground limestone in the place of stone screenings. The use of ground limestone presents a surer continuity of uniformity. To illustrate just what

is meant, let us assume that the hopper is of sufficient size so that 1,000-pound batches can be mixed, as the limestone almost always comes in 100-pound bags. This means that a proper amount of limestone dust can always be added. A visual inspection of the section constructed using limestone indicates a slightly more stable surface, and I am of the opinion that in the long run the operation can be reduced slightly in cost by using limestone rather than stone screenings. My reason for this is that the limestone is not heated. It is added to the hopper direct from the bag, so that both elevators can be used in raising sand to the dryer.

It has been found that the output in general is slightly slowed up because one elevator does not carry sufficient sand to the dryer when the other elevator is used for raising stone screenings, so that I feel that a greater output can be obtained, even though it will be necessary for a few revolutions of the pug to mix the sand and limestone dust before adding the asphalt.

DISCHARGE OVER SIDE WEIRS WITH AND WITHOUT BAFFLES

BY RICHARD G. TYLER,* JOHN A. CAROLLO,† AND NORMAN A. STEYSKAL†

(Presented before the Sanitary Section, B. S. C. E., January 31, 1929)

THE purpose of this paper is twofold: first, the experiments and data on the discharge of side weirs as obtained by different investigators will be discussed; and second, the tests of the authors on side weirs with and without baffles will be described. It is not proposed to present a new formula for discharge over side weirs, but the results obtained by other investigators vary so widely that the present tests were undertaken to determine the relative accuracy and usefulness of the formulas at present in use.

The type of structure referred to herein as a side weir or side spillway consists of a weir built in the side wall of a conduit for the purpose of withdrawing part of its flow. Very little work has been done of an experimental nature to determine the discharge over such weirs, due to their limited use and since side weirs are not used for measuring rates of flow. With the growth of cities, relief and intercepting sewers become necessary, and the adaptability of side weirs for such diversion purposes has suggested this study.

In the second edition of Metcalf & Eddy's "American Sewerage Practice," Vol. 1, page 631, *et seq.*, will be found a brief discussion of certain formulas which have been suggested for computing the discharges over side weirs. These formulas are as follows:

The Coleman and Smith formula is —

$$Q = 0.671 l^{0.72} h_1^{1.645}$$

$$l = 0.548 b v h_1^{0.13} \left(\sqrt{\frac{1}{h_2}} - \sqrt{\frac{1}{h_1}} \right)$$

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† Graduate Student, Massachusetts Institute of Technology, 1928.

The Babbitt formula is —

$$l = 2.3 v D \log \frac{h_1}{h_2}$$

The Engels formula is —

$$Q = 3.32 l^{0.83} h^{1.67}$$

In which

Q = discharge over the side weir in cubic feet per second.

l = length of weir crest in feet.

h = head on lower end of weir in feet in Engels formula.

h_1 = head on upper end of weir.

h_2 = head on lower end of weir in Babbitt and Coleman and Smith formulas.

v = mean velocity in the main channel above the weir.

D = diameter of circular sewer.

The Coleman and Smith formula was based upon experiments using a small flume $4\frac{3}{4}'' \times 6''$ in sections. It is apparent at a glance that the discharge obtained by this formula is considerably less than that obtained by Engels. For unit head and length of weir crest, the discharges obtained for these two formulas would equal their coefficients, respectively, giving practically five times the quantity of flow by the Engels formula as obtained by that of Coleman and Smith. It is possible that the latter have not taken into account the law of hydraulic similitude in adapting the results of their experiments to practical use.

The formula of Babbitt was derived from experiments on circular pipe sewers, and contains the term D . It cannot be used for rectangular channels, so the present tests do not furnish information that can be used to check its accuracy. It contains a term for the velocity of approach in the main channel which has an important bearing upon the quantity discharged over the weir. If, however, cases were taken where, at two different values of h_1 the velocities in the main sewer were equal, as at half and full depth of flow, and a value for h_2 was taken so that $\frac{h_1}{h_2}$ was

equal for the two cases, this formula would give an equal length of weir for both, though it is obvious that for the case of the full sewer the discharge would be greater than in the case of the sewer flowing half full.

It would appear, therefore, that more data are desirable before determining the limits within which this formula can be used. Professor Babbitt's experiments were made on 18 and 24-inch pipe sewers with weirs from 16 to 42 inches in length.

Hubert Engels has carried out more extensive tests* than the other investigators whose data are available to the authors; and, since the present experiments are more nearly comparable with his data, his formula will be discussed more in detail. Table 1 gives the data from his tests. The units have been converted from the metric to the English system, and the symbols are as shown on Fig. 1.

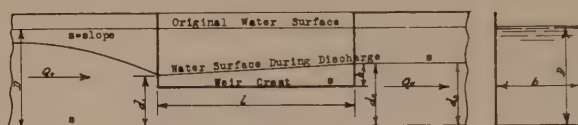


FIG. 1.— SHOWING WATER SURFACE PROFILE BEFORE AND DURING DISCHARGE OF SIDE WEIR

* "Forschungsarbeiten auf dem Gebiete des Ingenieurwesens," papers 200 and 201, by Hubert Engels, 1917.

TABLE 1. — DATA ON SIDE WEIRS AS GIVEN BY HUBERT ENGELS
[Dimensions in feet and seconds]

RUN	S	b	l	Z	D	h	d ₁	d ₂ =d ₃	Q _t	Q _c	Q _w	V= $\frac{Q}{bD}$
4	.001	.672	1.67	.312	.49	.082	.36	.39	.519	.396	.123	1.58
5	.001	.672	4.94	.312	.49	.059	.33	.37	.519	.364	.155	1.58
7	.000091	6.58	14.80	.49	.69	.105	.59	.60	4.43	3.61	.82	.98
9	.001	1.98	1.64	.83	1.06	.177	.93	1.01	6.35	6.00	.353	3.03
10	.001	1.98	3.28	.83	1.06	.161	.94	.99	6.35	5.86	.494	3.03
12	.00033	1.98	1.64	.83	1.44	.371	1.17	1.20	5.42	4.31	1.11	1.90
13	.00033	1.98	6.56	.83	1.44	.216	.97	1.05	5.42	3.64	1.78	1.90
14	.00033	1.98	13.12	.83	1.44	.167	.91	1.00	5.42	3.43	1.99	1.90
15	.00033	1.98	19.68	.83	1.44	.154	.89	.99	5.42	3.37	2.05	1.90
16	.00033	1.98	26.24	.83	1.44	.144	.90	.98	5.42	3.30	2.12	1.90
17	.00033	1.98	29.52	.83	1.44	.138	.87	.97	5.42	3.28	2.14	1.90
18	.00033	1.98	32.81	.83	1.44	.125	.86	.96	5.42	3.21	2.21	1.90
19	.00033	1.98	1.64	.83	1.056	.161	.98	.99	3.66	3.37	.29	1.75
20	.00033	1.98	3.28	.83	1.056	.141	.95	.97	3.66	3.28	.378	1.75
21	.00033	1.98	6.56	.83	1.056	.108	.91	.94	3.66	3.14	.52	1.75
22	.00033	1.98	13.12	.83	1.056	.089	.89	.92	3.66	3.04	.62	1.75
23	.00033	1.98	19.68	.83	1.056	.075	.87	.91	3.66	2.99	.67	1.75
24	.00033	1.98	26.24	.83	1.056	.072	.86	.90	3.66	2.96	.70	1.75
25	.00033	1.98	32.81	.83	1.056	.069	.86	.90	3.66	2.95	.71	1.75

One of the first things to be noticed in trying to compare the data from the various tests is the variation in slope of the water surface in the plane of the weir as reported. This is shown in Fig. 2, where the line marked *A* shows the surface profile as observed by Babbitt and by Coleman and Smith. The line *C* gives the profile as observed by Engels, while the authors found this profile as represented by the line *B*. It will be noted that line *A* gives a greater head at the upper than at the lower end of the weir, while the reverse is true for lines *B* and *C*. These variations in surface contour are probably due to the difference in velocities in the main channel at which the experiments were conducted.

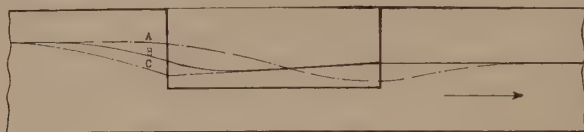


FIG. 2.—PROFILE OF WATER SURFACE AS OBSERVED BY DIFFERENT INVESTIGATORS

- A—Surface profile as observed by Babbitt
- B—Surface profile as observed by the authors
- C—Surface profile as observed by Engels

From Table 1 it will be seen that Engels' velocities were from 1.75 to 1.90 feet per second for most of the tests. In Table 2, giving the authors' data for side weirs, these velocities are seen to vary from 1.43 to 2.74. It is probable that Babbitt's experiments were run at a higher velocity, such as is common in sewers, though he does not give these data as to his velocities. It would seem that for conditions as represented by line *A*, a term for the velocity in the main channel is necessary, though, with the conditions found by Engels and shown by line *C*, where the depth in the main channel below the weir is the same as at the lower end of the weir crest, it is probable that a condition of equilibrium between velocity and pressure heads has been reached, so that the head in his formula includes the effect of this velocity. For higher velocities, especially with short lengths of weir, this condition of equilibrium may not be reached, and a surface profile *A* or *B* would result where the Engels formula might not apply. In Fig. 3, the data from Tables 1 and 2 are shown graphically. Curves for the Engels formula are also plotted for lengths of weir crest of 1, 5 and 20 feet. The lines marked *D* represent Engels' data for the weir-lengths shown. The lines *C* were constructed with the assistance of Fig. 4, from which points were taken for the desired lengths of weir crest. These lines represent

TABLE 2. — DATA ON SIDE WEIRS FROM SERIES I
[Dimensions in feet and seconds]

RUN	b	l	Z	D	h	Q_t	Q_w	$V = \frac{Q}{bD}$
1	1.5	1.5	.174	.625	.459	2.32	.366	2.48
2	1.5	1.5	.174	.666	.501	2.05	.600	2.06
3	1.5	1.5	.174	.692	.534	1.915	.716	1.84
4	1.5	1.5	.174	.757	.601	1.63	1.000	1.43
5	1.5	1.5	.174	.666	.466	2.00	.483	2.48
6	1.5	1.5	.174	.635	.415	2.05	.383	2.55
7	1.5	1.5	.174	.600	.415	2.18	.283	2.74
8	1.5	1.5	.174	.665	.482	1.98	.450	2.43

if this is compared with the Engels data for the same length of weir, it is found to differ widely from it. The slope of this line will be expressed by a formula containing h^3 instead of $h^{1.67}$.

In deriving his formula, Engels took the weir formula

$$Q = 2/3 \mu l h \sqrt{2gh}$$

and assumed that the sum of the exponents of l and h must be constant and equal to 2.5. Taking $2/3 \mu = 0.414$, the formula heretofore given

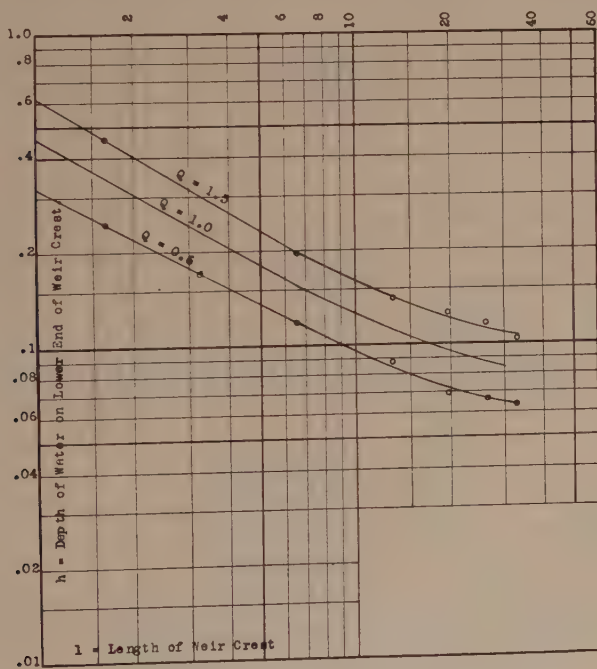


FIG. 4.—CHART SHOWING RELATIONSHIP BETWEEN l AND h

was derived. The authors' data, however, would indicate that the sum of the exponents of l and h may not be constant, or at least may be larger than 2.5. While Engels' assumption is approximately true for transverse weirs, it is not necessarily true in the case of side weirs. The velocity in the main channel has the reverse effect with side weirs from that with transverse weirs, as the discharge varies inversely with the velocity in the former and directly with it in the latter.

Since side weirs have been designed using the Francis weir formula with end contractions, it may be interesting to compare the results

obtained from the Francis and Engels formulas. Fig. 3 shows discharge curves for weir crests of 5 and of 20 feet computed by the Francis formula, which may be compared with the similar curves for that of Engels.

For $l=5$ ft., both formulas give equal discharges for $h=0.6$ ft. approximately, while for smaller heads the Francis formula gives larger discharges (by 44% for $h=0.1$ ft.), while the reverse is true for greater values of h . As l increases, the difference in results obtained by the two formulas increases. For $l=20$ ft., for example, the Francis formula gives discharges greater than the Engels formula by 114 per cent for $h=0.05$ ft., or 63 per cent for $h=1.0$ ft. These figures will suffice to indicate that errors of considerable magnitude may result from the use of the Francis formula, the error increasing with $\frac{l}{h}$.

While the Engels formula is the only formula used at present which appears suitable for side weirs in other than circular conduits, it should be noted that for the extreme case where the width of sewer is great and the velocity in the conduit is very small, the weir discharge should approach that obtained by the Francis formula, which the Engels formula does not do. This would require a formula where Q varied inversely as some function of v and directly as $lh^{3/2}$.

BAFFLED SIDE WEIRS

In order to secure a side weir which would give a maximum flow for a given length of weir crest, and which would appear to be more certain in its action, Glenn D. Holmes, Chief Engineer of the Syracuse Intercepting Sewer Board, constructed a baffled weir for the egg-shaped Crouse Avenue sewer, which is reproduced in Metcalf & Eddy's "American Sewerage Practice," Vol. 1, 2d edition, page 641. This consists of a baffle constructed diagonally across the upper part of the main sewer with a horizontal cut-water at its lower edge. This baffle or deflector wall was supposed to divert that portion of the water above the horizontal cut-water and force it over a side weir into a storm water outlet. Mr. Holmes modified this design later to omit the cut-water slab, and utilized two deflecting baffles set at an angle of 45° with the direction of flow, and with the upstream baffle slightly higher than the downstream baffle.

This type of structure appeared to have certain obvious advantages over the plain side weir, so the authors undertook to carry on experiments to determine the effect of baffles on the weir discharge, together

with the position of baffle which would make this discharge a maximum. These experiments were made with an 18-inch crest of weir located in the 18"×18" flume used for the side weir experiments. All tests were made with the weir crest .174 foot above the bottom of the channel, and with baffles placed at angles of 90°, 67° and 30°, respectively, with the axis of the main channel. These baffles were located at the lower end of the weir and with the lower edge of baffle at the elevation of the weir crest. Depth of flow was measured at numerous points across and along the flume by means of piezometers, care being taken to eliminate possibilities of errors sometimes encountered when using piezometers. Table 3 gives the data obtained from the tests. Additional tests are now in progress with different values of l , Z , h and v . These data are obviously too meager for the drawing of conclusions, but the following indications are of interest.

The discharge over the side weir is increased by the use of baffles as used, the greatest increase being with the baffle at right angles to the channel. The 67° baffle gave a slight increase in discharge, with the 30° having but slight effect. These discharges are not exactly comparable with the side weir data, as the head had to be measured at the upstream end of the weir, except for the 90° baffle with which it was measured at both ends. Here, the upper measurement was about 0.07 foot greater than the lower. The 90° baffle has the effect of throttling the main channel, and the discharge under it might be likened to that under a gate or the discharge through an orifice with contraction on one side only, *i.e.*, under the edge of the baffle. This contraction at the higher velocities experimented with amounted to as much as 1 to 1½ inches, and the depth of flow below the baffle was less than the critical depth, so that a hydraulic jump occurred downstream, its position being fixed by regulating the velocity below the jump. If the jump was forced back against the baffle, it decreased the head, causing flow under the baffle, thus decreasing the discharge Q_c in the channel below the weir and increasing the discharge over the weir. The effect of the baffle on the weir discharge was to convert part of the velocity head into pressure head, thus building up a greater head on the weir with a corresponding increase in discharge. With the 67° and 30° baffles, the contraction took place, giving the appearance of a velocity component at right angles to the baffle. This threw the discharge against the side of the channel away from the weir, producing a jump. While the discharge over the side weir without baffles begins slowly as the water rises in the main channel above the elevation of the weir crest, when the 90° baffle is used, as soon as the water comes into contact with its

TABLE 3. — TESTS ON BAFFLED SIDE WEIRS

(Dimensions in feet and seconds)

[h₁=head at upstream end of weir crest]

Series II. — Baffle at 90° to Main Channel

RUN	b	l	z	D	h ₁	h ₂	Q _t	Q _w	Q _c	$\frac{Q_t}{V=\frac{Q_t}{bD}}$
1	1.5	1.5	.174	.787	.57	.48	2.78	1.082	1.698	2.36
2	1.5	1.5	.174	.696	.52	.45	2.42	.886	1.534	2.32
3	1.5	1.5	.174	.766	.53	.44	2.49	.867	1.623	2.17
4	1.5	1.5	.174	.909	.63	.54	2.65	1.165	1.485	1.94
5	1.5	1.5	.174	.750	.54	.44	2.52	.917	1.603	2.24
6	1.5	1.5	.174	.708	.51	.45	2.43	.763	1.667	2.29
7	1.5	1.5	.174	.750	.54	.48	2.64	.975	1.665	2.35
8	1.5	1.5	.174	.679	.49	.43	2.35	.785	1.565	2.31
9	1.5	1.5	.174	.775	.59	.59	2.27	1.240	1.030	1.95

Series III. — Baffle at 67° to Main Channel

1	1.5	1.5	.174	.92	.65	—	2.72	1.12	1.60	1.97
2	1.5	1.5	.174	.77	.55	—	2.76	.80	1.96	2.39
3	1.5	1.5	.174	.65	.45	—	2.18	.41	1.77	2.24
4	1.5	1.5	.174	.76	.53	—	2.47	.73	1.74	2.17
5	1.5	1.5	.174	.73	.50	—	2.45	.65	1.80	2.24
6	1.5	1.5	.174	.71	.49	—	2.43	.62	1.81	2.28
7	1.5	1.5	.174	.74	.53	—	2.67	.75	1.82	2.41
8	1.5	1.5	.174	.65	.46	—	2.34	.53	1.81	2.40
9	1.5	1.5	.174	.79	.61	—	2.28	1.13	1.15	1.93

Series IV. — Baffle at 30° to Main Channel

1	.	.	1.5	1.5	.174	.93	.64	—	2.64	.97	1.67	1.89
2	.	.	1.5	1.5	.174	.75	.51	—	2.80	.60	2.20	2.49
3	.	.	1.5	1.5	.174	.68	.46	—	2.79	.42	2.37	2.74
4	.	.	1.5	1.5	.174	.76	.51	—	2.44	.60	1.84	2.14
5	.	.	1.5	1.5	.174	.72	.57	—	2.45	.53	1.92	2.27
6	.	.	1.5	1.5	.174	.67	.44	—	2.47	.40	2.07	2.46
7	.	.	1.5	1.5	.174	.69	.45	—	2.63	.45	2.18	2.54
8	.	.	1.5	1.5	.174	.82	.59	—	2.55	.92	1.63	2.07
9	.	.	1.5	1.5	.174	.59	.36	—	2.30	1.41	1.89	2.60

lower edge, a head builds up, and the weir discharge starts with an appreciable increment.

One of the conditions to be met in the construction of side weirs is to design a structure which will pass a given maximum quantity of sewage down the main channel, while at the same time the weir should not begin to discharge at too small a sewage flow. In other words, if a side weir is designed with Engels' formula to have the desired depth of flow in the channel below under maximum flow conditions, the weir would have to be at a lower elevation than this depth of flow in the sewer, so that it would begin to discharge at considerably lower flow rates. However, with the usual practice of passing a certain amount of diluting water down the sewer, it is possible to design the weir crest at a height equal to the depth of flow in the sewer when the dry weather maximum flow rate is reached, and then construct a sufficient length of weir so that only the desired quantity of sewage and storm water is carried on down the main sewer.

A baffled side weir has the advantage of discharging from 20 to 30 per cent more water per foot of weir crest than does the unbaffled side weir, while it also gives more positive control in the range of discharges in the main sewer below the structure. By making the height of the lower edge of the baffle adjustable, it should be possible, under actual operating conditions, to take care of any reasonable errors in design of weir crest which might result from the inadequacy of the data at present available on the discharges of such structures. It would, therefore, appear to have both the advantage of economy and of accuracy in design.

The use of side weirs with or without baffles is somewhat limited. The siphon spillway has an advantage in efficiency, both as to the quantity of water discharge per foot of length of structure, and as to its ability to control the surface level in the sewer between narrower limits. The side weir, however, has the advantage of simplicity, and is particularly adapted for use as a relief structure to be installed in existing sewers which have become surcharged.

OF GENERAL INTEREST

FIELD METHOD OF ADJUSTING A TRANSIT

*By George L. Hosmer**

The following method of adjusting a surveying instrument may perhaps be just another instance of "no new thing under the sun," but as I never happened to hear of it before, and as it may be useful to some one, I will jot it down for what it is worth.

The cross-hairs in a transit were broken, and it became necessary to remove the diaphragm from the telescope in order to insert new ones. When the diaphragm was again placed in the telescope it was necessary to make a complete readjustment of the cross-hairs; that is, (1) for verticality of the vertical hair; (2) for collimation of the vertical hair; and (3) adjustment of the horizontal line of sight when the telescope bubble is centered in its tube.

The first two adjustments can be made by one person and present no difficulty; these were made in the usual manner. The third adjustment, when made in the field, is usually done by the "peg method," which requires two persons and may have to be repeated several times before the adjustment is satisfactory. It occurred to me that a quick way to adjust the horizontal hair would be to set up a good level in front of the transit and use it as a collimator. If the level

were in good adjustment and its bubble centered, then the direction of its horizontal hair as seen through the transit when looking into the object glass of the level (Fig. 1) would be a horizontal line. By moving the diaphragm of the transit so as to make the horizontal hair of the transit coincide with that of the leveling instrument, the transit would be put into as good adjustment as the level itself. This is, of course, the same sort of device as that used by instrument makers to adjust instruments in the shop.

If, however, the adjustment of the leveling instrument happened to be in error, then the transit sight line would be in error by the same amount. The positions of the instruments and the error of adjustment are shown in Fig. 1. The dotted line represents the true horizontal line, and the full lines show the sight lines of the two telescopes; these sight lines are exactly parallel to each other.

After this adjustment was made, it then became apparent that the adjustment of the level could be tested in a simple manner; that is, if the leveling instrument were faced about and some distant object found which coincided with the horizontal hair, then the line

* Professor of Geodesy, Massachusetts Institute of Technology, Cambridge, Mass.

of sight to this object would be as much above the true horizontal as the transit sight line was below it (or *vice versa*), since the level telescope had been reversed, end for end. The bubble of the leveling instrument had to be centered independently, of course, in each position.

The result of this test was that the cross-hair of the level just hit the top of a chimney some two miles away, while the transit cross-hair (looking

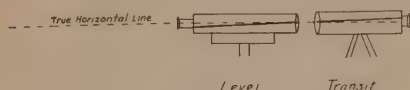


FIG. 1



FIG. 2

Showing positions of instruments for making the adjustment

directly at the object) covered a point a little way down on the chimney. (Fig. 2.) The diaphragm of the transit was then moved so that the cross-hair sighted a point halfway *up* from the lower point to the top of the chimney; this completed its adjustment. At the same time, the level itself was adjusted by moving its cross-hair so as to strike a point halfway *down* from the top of the chimney to the point first sighted by the transit. A second trial showed that the transit cross-hair sighted the level cross-hair, when the latter was used as a collimator, and that the cross-hairs of both instruments hit the same point on the chimney when sighted directly at it.

In the preceding description, the instrument to be adjusted was assumed to be a transit, but it is evident that a level could be adjusted by exactly the same process.

Tide Table, Boston Harbor and Vicinity, 1929

The Department of Commerce has just issued the first edition of a tide table, giving for each day of the year 1929 the predicted times of high and low water at Boston, and tidal differences by means of which corresponding predictions may be readily obtained for numerous other places in Boston Harbor and vicinity, including the outer coast extending from Thacher Island on the north to the head of Cape Cod Bay on the south. It is proposed to issue a similar publication annually.

In addition to the tidal data, the publication also includes the phases of the moon (incorporated in the table of predictions), and the times of sunrise, sunset, moonrise and moonset for Boston.

It is issued in convenient pocket size, and is prepared primarily for the use of those interested in the rise and fall of the tide in Boston Harbor and general vicinity. Local water men, yachtsmen, fishermen, hunters, and others, will find this small pamphlet a useful handbook.

The sale price of this publication is five cents per copy. Copies may be obtained from the Director, Coast and Geodetic Survey Field Station, Room 21, 92 State Street, Boston, Mass.

Estimating Construction Costs

The Morton C. Tuttle Company of Boston has recently distributed in pamphlet form reprints from the Architectural Forum of "Pre-Determined Construction Costs the Essential of Economy in Building Design," by Clayton W. Mayers. This is a subject of more than ordinary interest to engi-

neers, and well worth reading. Comparisons of the costs of different types of structures are made in detail for buildings of joist construction, mill construction, reinforced concrete construction, and steel frame fireproofed with concrete slabs. A preliminary estimate of the cost of a fireproof office building is also given. The introductory matter is as follows:

Nearly every architect is all too well acquainted with the unpleasantness experienced in completely revising a set of plans and specifications on which bids have been taken and costs found to be prohibitively high. Such an experience is, however, very much more disagreeable when the procedure is necessary in order that the cost of the finished project be kept within a set limit which heretofore the architect had felt certain would be met by the requirements of his design. The fact remains, however, that he has either been too liberal in refinements and ornamental details or, — what is more unfortunate, — embarked on a project the size of which was too large in the first place. Whatever may be the reason for the necessity of cutting down the design, the work which must be done is not only irritating and disagreeable but expensive, in that the process calls for seemingly endless changes to drawings and specifications.

Frequently the result of all this work of revision produces an unbalanced design not at all in keeping with what the architect had originally intended or what the client had expected. Were it not for the pressure of time, making a fresh start might be the wisest way out, but generally the client has already become impatient to begin operations, and now being obliged to forego many of the features incorporated in the original design, becomes more and more disgruntled. Thus the architect is placed in an exceedingly embarrassing position. It is expected that he will be able to make changes quickly which will result in a lowered cost, all without impairing seriously the attractiveness or useful-

ness of the structure. Eventually the changes in plans and specifications are completed and, as a result, the architect becomes involved with the design and construction of a building very different from his original conception, one in which he can take but small if any pride; in fact, it may be that he would much prefer that he had been disassociated with the project altogether. Perhaps, too, on account of the many hours spent in revising the drawings, the architect finds that he is actually out of pocket, a condition which cannot help but add to the keenness of his disappointment. Much better had he planned a somewhat smaller or more simple structure, a building development in which he could take justifiable pride.

There is a reason for such a state of affairs, and an avoidable reason. A wrong start has been made, and when the start is wrong the course is also wrong, and the result correspondingly unsatisfactory. It may be that the size of the project as originally visualized did not correspond with the amount of funds available for its development. It may be that the size was correctly established, but that the character of the structure and materials and the elaborateness of the developed details were to blame for the disappointingly high figures submitted by the contractors. Whatever the reason, this unhappy condition could have been averted had the architect given proper consideration to "cost" at the critical time, — namely, during the early stages of the development of the plans.

On this point of cost, the architect, having obtained some generalizations as to what the client could spend, might have made certain mental reservations as a safeguard against surprise, and prepared sketches accordingly. The estimate of cost perhaps consisted of a simple calculation in which the cubic contents of the proposed structure were multiplied by a cost per cubic foot, which represented the best guess of which, at the moment, the designer was capable. Making such an estimate frequently constitutes the sole means

of judging cost of the building until the designer's plans have been fully elaborated, his specifications written, and the whole put to the test of competitive bids from a number of contractors. All through this period of designing, there is no certainty that the design will prove capable of development within the limits of cost previously set. There is always a chance, however, that the design may have sufficient appeal to permit an expansion of the limits of cost as set by the client. In such a case, the architect may be more fortunate than skillful!

So many factors enter into the cost of construction work that it is only by making preliminary estimates during the early stages of design that an architect can be reasonably certain that he is on the right road. Such estimates should be the product of a building cost expert working closely with the architect. It is only by such a procedure that the architect is assuring his client of skillful and competent service. Where a building—whether it is an office structure, a factory, a hotel or a large apartment house—must return income proportioned to the capital investment which it represents, such procedure alone is intelligent and fair. This cost expert should be a man in close touch with the actual cost of work done in the construction field. He should be working not merely from records, in many instances established by persons and under conditions unfamiliar to him, but from information gained at first hand, which should be extensive enough to permit his qualifying to speak with a certain degree of authority. The architect can depend upon the information so furnished in working out the design of the entire building, from footings to parapet cap. By the judicious use of such information he should at no time be ignorant of the proper cost of the structure being developed. A budget estimate of cost should be made which—instead of being a guess predicted on a hasty calculation of probable cubic contents—represents a reasonably careful computation of the cost of each major element in the proposed structure

and a totaling of them all. An alteration in the character or form of any one of these elements will, obviously, alter the total cost. Hence, with his building problem thus broken up into logical and understandable elements, the architect is in a position to view his alternatives on the basis of good reason and to determine whether additional expense is in any way or at any time justified, or whether exactly the opposite viewpoint must be taken in safeguarding the client's interests. Uncertainty of cost should be as far as possible eliminated, thereby saving the architect the unhappy experience previously described, and this can be done by the construction cost expert.

Answering the question as to why the architect cannot get his good friend Mason, the contractor, to give him estimates such as we have furnished here, I believe in the majority of cases where architects ask builders for estimates of this sort that the builder is more interested in making an impression upon the architect than he is in giving the architect his unbiased judgment. To most builders an opportunity to make such an estimate for an architect offers an opportunity to sell the architect the idea that he, the builder, must be tremendously economical in his work. To drive this idea home he is often likely to make very low approximate estimates which, of course, are misleading. Again, few builders have gone to the trouble and expense of compiling statistics on the efficiency of men on various operations. To make such a compilation requires, first, a large volume of construction work, and also a very efficient cost-keeping system on the site in order that such data be available. We believe it is quite customary for concerns who have a large amount of estimating data to guard it very carefully. Free estimates are usually looked upon by architects as being nearly worthless and very likely to be confusing on account of their lack of frankness.

Copies of the pamphlet may be obtained from the Tuttle Company.

Hydraulic Experimentation

A series of lectures, beginning March 21, on "Hydraulic Experimentation" is to be given at the Massachusetts Institute of Technology by Dr. Ing. Theodor Rehbock, professor of hydraulics at the Technische Hochschule of Karlsruhe, Germany.

The lectures will be illustrated by moving and still pictures. The measurement of water, model experimentation, laws of similarity, river flow, laboratory work at Karlsruhe and rules for labora-

tory construction and procedure are among the subjects to be treated.

The January, 1928, issue of the JOURNAL was devoted to the "Application of Laboratory Research to the Study of Hydraulic Problems" by Dr. George H. de Thierry, and in this issue were many references to Dr. Rehbock's investigations.

Complete information as to dates may be obtained by telephoning the Civil Engineering Department Headquarters at the Massachusetts Institute of Technology.

PROCEEDINGS OF THE SOCIETY

MINUTES OF MEETINGS

Boston Society of Civil Engineers

FEBRUARY 20, 1929. — A regular meeting of the Boston Society of Civil Engineers; was held today in Lorimer Hall, Tremont Temple, and was called to order by the President, Charles B. Breed, at 7.15 P.M. This was the annual Joint Meeting with the following student engineering societies: Northeastern University Section; M. I. T. Student Chapter, American Society of Civil Engineers; Harvard Engineering Society; and Tufts Civil Engineering Society.

There were about 400 present at the meeting and nearly 300 attended the buffet supper and smoker which preceded it.

The Secretary announced the names of those elected to membership in the Society, as follows:

January 23, 1929. *Grade of Member:* John A. Billings, John R. Carroll, Harold F. MacWilliams,* Carl H. Nelson.* *Grade of Junior:* Wallace O. Lindquist.

February 20, 1929. *Grade of Member:* William J. Backes, Harry Cikins, Stuart S. Davis, Albert Haertlein, Russell S.

Harmon, George H. Meserve, Jr.,* Frank K. Niechcay,* Benjamin R. Rosenberg, Rudolf S. Slayter, Charles E. Thrasher. *Grade of Junior:* De Forrest H. Caldon, Richard P. Crockett, John W. Greenleaf, Jr., Maurice F. Hunt, Cornelius P. Kelleher, Oral Leavitt, Howard F. Lord, James A. McCarthy, Alfred T. Stamp, Vernon L. Stone, Frederick W. Wagner, Abraham Woolf.

The President presented William F. Uhl, Hydraulic Engineer, Chas. T. Main, Inc., who gave an illustrated talk on the "Hydro-Electric Development of the Mongaup River." This project includes five dams and power plants on the Mongaup River in the State of New York, for the Rockland Light and Power Company. Charles H. Tenney & Co. are managers and engineers for this public utility, and Chas. T. Main, Inc., were Consulting Engineers on the hydraulic features. The total head developed 740 feet and the capacity 30,000 kw. Two of the plants are completed, one is now under construction, and two more will be started soon.

At the conclusion of Mr. Uhl's address the following members of the Society

* Transfer from Grade of Junior.

took part in the discussion: Prof. H. K. Barrows of Massachusetts Institute of Technology, A. C. Eaton of the New England Power Construction Corporation, H. M. Turner, Consulting Engineer, and E. A. Graustein, Consulting Engineer. After these prepared discussions Mr. Uhl answered many questions concerning this power project.

Meeting adjourned about 9.30 P.M.

J. B. BABCOCK, *Secretary*.

Sanitary Section

JANUARY 31, 1929. — The meeting was preceded by dinner at Patten's at 6 P.M. About twenty members and guests were present at the dinner.

Meeting was called to order at 7.20 P.M. by the Chairman. Twenty-six members present.

The report of the committee appointed by the Section to consider the feasibility of organizing a New England Sewage Operators Association was presented by F. W. Gilcreas. This report was adopted and placed on file.

It was voted to instruct the Chairman to appoint a committee of three to nominate officers for the Section for the coming year. The Chairman appointed A. D. Weston, H. P. Eddy, Jr., and C. F. Joy.

Prof. C. M. Spofford opened the discussion of the question, "Is Public Health Engineer" a better title than "Sanitary Engineer"? The Chairman read a letter from Prof. John H. Gregory, stating his preference for the title "Sanitary Engineer." After several of the members present had discussed the question it was *Voted* that the Section go on record in favor of the title "Sanitary Engineer."

The paper of the evening was presented by Prof. Richard G. Tyler of the Massachusetts Institute of Technology. The subject was "Discharge of Side Weirs with and without Baffles."

Professor Tyler presented the results of some research studies carried on at M. I. T., and his talk was illustrated with lantern slides. A discussion of the paper followed, and the meeting adjourned at 9.30 P.M.

H. P. BURDEN, *Clerk, pro tem*.

Designers Section

FEBRUARY 13, 1929. — Chairman W. D. Henderson called the meeting to order at 6.10 P.M. After the minutes of the previous meeting had been read and approved, the clerk read the names of those who had requested copies of the syllabus of the January meeting and who had not obtained them previously.

A motion was made that a nominating committee be appointed to prepare a list of candidates for the Section offices for the coming year. The motion having been acted upon favorably, Mr. Henderson selected past Chairmen Waldo F. Pike and Scott Keith, and also Mr. LeRoy Hersum, to serve on this committee.

"The Structural Design of Steel Transmission Line Towers" was the subject taken by Mr. H. O. Weber of the Stone & Webster Engineering Corporation, and Mr. C. A. Booker of the New England Power System. The speakers had collaborated in the preparation of their papers, which, with the numerous slides which they used, created a very interesting presentation of the subject. A paper prepared by Mr. Sydney A. Martin, who was unable to be present, was read for him by the clerk. A record of the papers was made by a stenographer.

After a discussion in which many of the 65 members and guests participated the speakers were given a rising vote of thanks.

The meeting adjourned at 8.20 P.M.

NORMAN P. RANDLETT, *Clerk*.

Highway Section

FEBRUARY 27, 1929. — The annual business meeting of the Highway Section was held Wednesday, February 27, in the Affiliation Rooms.

The Chairman, LeRoy M. Hersum, called the meeting to order at 7.05 P.M. The minutes of the meeting held January 23, 1929, and the report of the Executive Committee for the past year were read and accepted.

The report of the Nominating Committee was read by Mr. R. W. Coburn. The Clerk was instructed to cast one vote for the nominees presented by the Nominating Committee.

The following officers were elected for the coming year:

Chairman — Prof. Charles B. Breed
 Vice-Chairman — James E. Lawrence
 Clerk — Ernest Mathers
 Members of the Executive Committee —
 LeRoy M. Hersum, Prof. James W.
 Ingalls, Edwin H. Rogers

After the business meeting H. C. Holden, District Engineer of the Massachusetts Department of Public Works, was introduced as the speaker of the evening. Mr. Holden gave a very interesting talk on the development of the hot mix type of highway surfacing by the Massachusetts Department of Public Works. He emphasized the economy of using this type of pavement in the Cape Cod area, and pointed out that the increasing truck traffic over Cape Cod roads would necessitate changes in pavement design.

A discussion followed, in which Messrs. Coburn, Bratt, Wertheim and Lawrence took part. Mr. Bratt discussed the hot mix type of highway pavement from the laboratory viewpoint.

There were 39 present at the meeting.

The meeting adjourned at 8.25 after according Mr. Holden a rising vote of thanks.

ERNEST MATHERS, *Clerk.*

APPLICATIONS FOR MEMBERSHIP

[March 20, 1929]

THE By-Laws provide that the Board of Government shall consider applications for membership with reference to the eligibility of each candidate for admission and shall determine the proper grade of membership to which he is entitled.

The Board must depend largely upon the members of the Society for the information which will enable it to arrive at a just conclusion. Every member is therefore urged to communicate promptly any facts in relation to the personal character or professional reputation and experience of the candidates which will assist the

Board in its consideration. Communications relating to applicants are considered by the Board as strictly confidential.

The fact that applicants give the names of certain members as reference does not necessarily mean that such members endorse the candidate.

The Board of Government will not consider applications until the expiration of fifteen (15) days from the date given.

For Admission

BRENAN, NORMAN WILLIAM, Boston, Mass. (Age 24, b. St. John, New Brunswick.) Am a student at Northeastern University. During co-operative periods have been employed by Barnes & Beal C.E., at Waltham and Newtonville, 1927-28; by Lewis Perkins, North Scituate, during the summer of 1928; by Aspinwall & Lincoln, 1928-29. Refers to H. B. Alword, J. W. Ingalls, K. D. Sylvester, C. A. Wolfrum.

CUMMINGS, WILLIAM FRANCIS, Marblehead, Mass. (Age 41, b. Charlestown, Mass.) Graduate of Mechanics Arts High School, Boston, then took course at Boston Y. M. C. A. evening school and Lowell Institute. Entered service of Boston & Maine Railroad in 1906 as chainman; held positions as rodman, transitman inspector and assistant engineer in location, survey and construction forces from 1906 to November, 1911; as instrumentman in maintenance of way department from November, 1911, to April, 1914; assistant engineer and valuation engineer from April, 1914, to April, 1927; engineer, maintenance of way, from April 1, 1927, to November 1, 1928; and as assistant chief engineer from November 1, 1928, to date. Refers to J. B. Babcock, J. D. Campbell, B. W. Guppy, F. C. Shepherd.

GERMAINE, JOHN F., Wollaston, Mass. (Age 30, b. Ottumwa, Iowa.) Graduated from high school at Bath, Me., in 1916, and attended evening school until 1922, studying engineering subjects. Entered the employ of Bath Iron Works in 1916 as apprentice engineer, the work consisting of design and construction of propelling machinery for ships; entered the employ of the Pejepscot Paper Company, at Brunswick, Me., in 1921 as draftsman; in

1923 became draftsman with the West Penn Power Company at Pittsburgh, and later sent to the field as construction engineer; in 1926 entered the employ of the New England Power Construction Company at Worcester; and at present employed by this company as assistant engineer in the hydraulic estimating department. Refers to *C. R. Bliss, E. A. Dow, A. C. Eaton, E. G. Lee.*

MCCULLY, COLEMAN CLYDE, Dorchester, Mass. (Age 35, b. Clinton, Mass.) Educated in the public schools of Fitchburg, and Worcester Polytechnic Institute. From May to December, 1913, was employed by the Erie Railroad as inspector, levelman and transitman in railroad construction; from December, 1913, to July, 1914, was assistant superintendent for John Marsch, Contractor, Southern New England Railroad; July, 1914, to February, 1916, estimator, Erie Railroad; February to May, 1916, draftsman, same company, then became assistant engineer to July, 1917; during 1917 worked for the J. F. Casey Company, the Fred R. Jones Company; from December, 1917, to July, 1920, was in United States Army with the Red Cross; from July, 1920, to April 30, 1927, was draftsman and assistant engineer, Boston & Maine Railroad; and from May 1, 1927, to date, assistant engineer with Metropolitan District Water Supply Commission. Refers to *C. L. Coburn, K. R. Kennison, D. N. Peaslee, F. C. Shephard, F. E. Winsor.*

MILLER, ALBERT A., Cambridge, Mass. (Age 21, b. Boston, Mass.) Graduated from Rindge Technical School in June, 1926, and entered Northeastern University that fall. Refers to *W. J. Alcott, C. O. Baird, C. S. Ell, J. W. Ingalls.*

PURRINGTON, WALLACE F., Concord, N. H. (Age 44, b. South Yarmouth, Mass.) Assistant chemist, Rhode Island Experiment Station, 1906-07; assistant chemist, New Hampshire State Board of Health, 1907-09; same office with Tennessee Food Commission, 1909-10; inspector, New Hampshire State Board of Health, 1910-17; materials engineer, New Hampshire Highway Department, 1917-18; scientific engineer, United States Public Health Service, 1918-19; materials

engineer, New Hampshire Highway Department, 1919-29; Commercial Testing Laboratory, Wallace F. Purrrington, Inc., 1929. Refers to *R. W. Coburn, A. W. Dean, E. S. Larned, W. C. Voss.*

SABAS, SEVERIN, Boston, Mass. (Age 28, b. Krasnopol, Russia.) Graduated from high school in Russia; six years of military service in aviation as a pilot. Came to America in 1925. Entered Northeastern University, where he is now a senior. Refers to *H. B. Alword, C. O. Baird, J. W. Ingalls, W. E. Nightingale.*

SPARROW, ARTHUR L., South Orleans, Mass. (Age 45, b. Malden, Mass.) Graduate of University of Maine with degree of B.S. in 1906. From 1906-07, in cost department of Russell & Erwin Manufacturing Company, New Britain, Conn.; has since practiced engineering on Cape Cod, mostly surveys, topographic or hydrographic, also a little at designing bridges and houses, and land court surveys. Refers to *W. C. Hawley, C. B. Humphrey, E. B. Richardson, N. W. Wade.*

For Transfer from Grade of Junior

BALLOU, GEORGE DEWEY, West Roxbury, Mass. (Age 30, b. Boston, Mass.) Graduate of Northeastern University with degree B.C.E. From 1922-26, engineer and estimator for the George A. Fuller Construction Company, Boston; from 1926 to date, superintendent of construction for Lowell Whipple Company, Worcester. Refers to *H. B. Alword, C. S. Ell, C. R. Gow, F. M. Gunby.*

BODEMER, PHILIP E., Cambridge, Mass. (Age 26, b. Cambridge, Mass.) Graduated from Northeastern University in 1924. Since that date has been connected with C. H. Gannett, C.E., until 1927, and then became a partner in C. H. Gannett Company, Civil Engineers. Refers to *H. B. Alword, M. A. Carchia, G. P. Frost, J. W. Ingalls.*

FRYE, HAROLD BUSTER, Boston, Mass. (Age 26, b. Boston, Mass.) Graduate of Northeastern University in 1925. In the summer of 1922 was employed as engineer's assistant for R. B. Bellamy, C.E.; in summers of 1923 and 1924 was em-

ployed as rodman for the Massachusetts Department of Public Works, Division of Highways; upon graduating became employed by the Massachusetts State Highway Commission as transitman; is now rated as senior engineering assistant. Refers to *H. B. Alword, C. S. Ell, J. W. Ingalls, Anselmo Krigger, W. E. Nightingale.*

HAMPE, FRITZ F., Jamaica Plain, Mass. (Age 30, b. Boston, Mass.) Graduate of Northeastern University in 1926. During co-operative periods was employed by Aspinwall & Lincoln from 1923 to August, 1926; draftsman, engineering department, town of Framingham, from October, 1926, to December, 1928. Refers to *C. O. Baird, H. D. Chase, L. A. Chase, W. E. Nightingale.*

NEW MEMBERS

Juniors

- JOHN W. GREENLEAF, Jr., 153 Naples Road, Brookline, Mass.
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 CORNELIUS P. KELLEHER, 197 St. Botolph Street, Boston, Mass.
 ALFRED T. STAMP, 10 Chickatawbut Street, Neponset, Mass.

DEATHS

- FRANCIS C. TUCKER . . Feb. 10, 1929
 FAYETTE S. CURTIN . . Feb. 15, 1929

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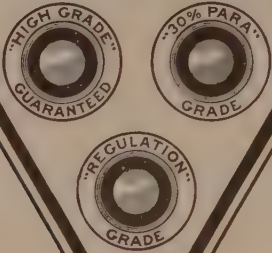
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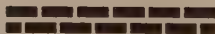
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